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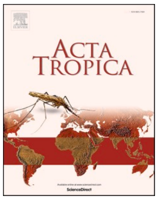

Modelling the risk posed by *Aedes* mosquitoes in Europe: Identifying research needs from public health stakeholders and field entomologists

Federico Romiti[a], Sarah Droghei[a], Dominic Brass[b], Cyril Caminade[c], Giovanni Marini[d], Bethan Purse[b], Kamil Erguler[e], Alessandro Albieri[f], Paola Angelini[g], Margo Blaha[h], Olivier Briet[i], Mattia Calzolari[j], Marco Carrieri[f], Silvio D'Alessio[k], Martina Ferraguti[l,m], Nicola Ferrari[n], Elisa Fesce[n,o], Eleonora Flacio[p,q], Miguel Garrido Zornoza[c], Pachka Hammami[r], Paul J Huxley[o,s], Adolfo Ibanez-Justicia[t,u], Carla Ippoliti[k], Emmanuelle Kern[o], Eleonora Longo[h], Alexander Meyer[v], Ruth Müller[w,x], Marta Pardo[y], Friederike Reuss[z], Greta Santarelli[aa], Lukas Sprengers[t], Stephanie Margarete Thomas[bb,cc], Wim Van Bortel[dd,ee], Chiara Virgilito[aa], Yiran Wang[o,ff], William Wint[gg,hh], Roberto Rosà[h], Daniele Da Re[d,h,*]

[a] *Istituto Zooprofilattico Sperimentale del Lazio e della Toscana, Italy*
[b] *UK Centre for Ecology & Hydrology, United Kingdom*
[c] *Abdus Salam International Centre for Theoretical Physics (ICTP), Italy*
[d] *Research and Innovation Centre, Fondazione Edmund Mach, Italy*
[e] *Climate and Atmosphere Research Center (CARE-C), The Cyprus Institute, Cyprus*
[f] *Centro Agricoltura Ambiente "G. Nicoli", Italy*
[g] *Regional Health Authority of Emilia-Romagna Region, Italy*
[h] *Center Agriculture Food Environment, University of Trento, Italy*
[i] *European Centre for Disease Prevention and Control (ECDC), Sweden*
[j] *Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia-Romagna, Italy*
[k] *Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise, Italy*
[l] *Departamento de Biología de la Conservación y Cambio Global, Estación Biológica de Doñana (EBD), CSIC. C/Américo Vespucio, 26, E-41092, Seville, Spain*
[m] *CIBER of Epidemiology and Public Health (CIBERESP), Spain*
[n] *Department of Veterinary Medicine and Animal Sciences (DiVAS), Università degli Studi di Milano, Italy*
[o] *MRC Centre for Global Infectious Disease Analysis, School of Public Health, Imperial College London, London, United Kingdom*
[p] *Scuola universitaria professionale della Svizzera italiana (SUPSI), Switzerland*
[q] *Swiss Mosquito Network, Switzerland*
[r] *Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), France*
[s] *University of York, United Kingdom*
[t] *The Netherlands Food and Consumer Product Safety Authority (NVWA), The Netherlands*
[u] *Netherlands Institute for Vectors, Invasive plants and Plant Health (NIVIP)*
[v] *University of Notre Dame, USA*
[w] *Department of Biomedical Sciences, Institute of Tropical Medicine, Antwerp, Belgium*
[x] *Department of Biomedical Sciences, Faculty of Pharmaceutical, Biomedical and Veterinary Sciences University of Antwerp, Antwerp, Belgium*
[y] *Centro de Estudios Avanzados de Blanes (CEAB-CSIC), Girona, Spain*
[z] *Goethe University, Institute of Occupational, Social and Environmental Medicine, Frankfurt, Germany*
[aa] *University of Rome "La Sapienza", Italy*
[bb] *Department of Biogeography, University of Bayreuth, Germany*
[cc] *Bayreuth Centre for Ecology and Environmental Research, Bayreuth, Germany*
[dd] *Institute of Tropical Medicine, Department Biomedical Sciences, Unit Entomology, Antwerp, Belgium*
[ee] *Institute of Tropical Medicine, Department Biomedical Sciences, Outbreak Research Team, Antwerp, Belgium*
[ff] *Grantham Research Institute on Climate Change and the Environment, Imperial College London, London, United Kingdom*
[gg] *Environmental Research Group Oxford, United Kingdom*
[hh] *Department of Biology, University of Oxford, United Kingdom*

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* Corresponding author at: Research and Innovation Centre, Fondazione Edmund Mach, Italy.
E-mail address: daniele.dare@fmach.it (D. Da Re).

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ABSTRACT

The growing public health burden of *Aedes* mosquito-borne diseases requires a comprehensive understanding of *Aedes* species biology, ecology, and vector competence. Eco-epidemiological modelling of *Aedes* vector species has grown significantly in recent years, driven by the increasing reports of outbreaks in endemic and non-endemic temperate areas, as well as the latitudinal and altitudinal range expansion of these vectors. A prominent example is the Asian tiger mosquito, *Aedes albopictus*, a competent arbovirus vector that has spread across most continents through the movement of humans and goods. Species distribution models and mechanistic models have been used to predict the spatio-temporal distribution and dynamics of this vector. However, despite the potential of these models to capture the vector distribution and dynamics, integrating them into practical monitoring, surveillance, and vector control activities remains challenging, often due to a lack of communication and model co-development between scientists and public health stakeholders. This paper reports the results of a workshop on vector modelling held in Bologna (Italy) in September 2024, which brought together European experts in disease modelling, public health stakeholders, and medical entomologists. The workshop identified key priorities for advancing the operational use of *Aedes*-focused quantitative models, including sustained investment in surveillance, improved representation of environmental and biological drivers, standardisation of model outputs, and the establishment of long-term, co-produced modelling frameworks embedded within public health workflows.

1. Introduction

Some mosquito species belonging to the *Aedes* genus, especially *Aedes aegypti* and *Aedes albopictus*, are responsible for the transmission of several arboviral diseases, such as yellow fever (Amraoui et al., 2016; Clements and Harbach, 2017; Johnson et al., 2002), dengue (Rezza, 2012; Souza-Neto et al., 2019), chikungunya (Lounibos and Kramer, 2016), mayaro (Brustolin et al., 2024; Souza-Neto et al., 2019) and Zika (McKenzie et al., 2019; Souza-Neto et al., 2019). The global expansion of these species has been facilitated by a combination of traits (Lounibos and Kramer, 2016), including egg resistance to desiccation and cold conditions (Kramer et al., 2020; Kreß et al., 2017, 2016), adaptation to urban environments, and anthropophilic feeding behaviour, which together increase their public health impact (Farooq et al., 2025). While *Ae. aegypti* is still predominantly confined to tropical and subtropical regions (European Centre for Disease Prevention and Control, 2023), *Ae. albopictus* has spread to every continent except Antarctica and is recognised as one of the world's most invasive species (Ahmed et al., 2022; Lowe et al., 2004; Roiz et al., 2024).

Recent outbreaks of *Aedes*-borne diseases in non-endemic regions have been largely driven by increased global travel and trade, which facilitate the movement of both mosquitoes and infected humans over long distances (Lim et al., 2023). *Aedes albopictus* has also demonstrated the ability to expand its latitudinal and altitudinal range, and extend its seasonal biting period in temperate countries (Battistin et al., 2024; Romiti et al., 2022). These trends are likely to be exacerbated by recent climate change and increasing thermal adaptations (Battistin et al., 2024; Farooq et al., 2025; Garrido Zornoza et al., 2024; Kramer et al., 2023, 2021; Marini et al., 2020; Radici et al., 2025; Thomas et al., 2012; Tippelt et al., 2020). Therefore, its introduction, in conjunction with the expansions of habitats in thermally suitable areas, poses new epidemiological challenges by increasing the risk of autochthonous transmission of arboviruses in previously unaffected regions (Ryan et al., 2019). For instance, large chikungunya and dengue outbreaks occurred in different regions of Italy and France over the last decade, causing hundreds of cases (Cattaneo et al., 2025; Manica et al., 2023; Sacco et al., 2024).

Even in countries where *Aedes*-borne diseases are endemic, the public health burden has risen substantially: Bangladesh experienced its most severe dengue outbreak so far in 2023, resulting in 1,700 deaths, while in 2024, a record-breaking global dengue outbreak caused over 13 million suspected cases and more than 8,000 deaths, mostly in Latin America (Hasan et al., 2025; Venkatesan, 2024). This growing burden underscores the need for improved surveillance and predictive tools to anticipate and mitigate the spread of *Aedes* mosquitoes and the diseases they transmit. Recent advances in vector modelling can help anticipate mosquito distribution, population dynamics, and seasonal patterns, providing critical insights for disease transmission and public health interventions.

A broad range of modelling approaches is available. Species distribution models, also called environmental niche models or habitat suitability models, use statistical associations between mosquito occurrence data (presence-absence, presence-only, or abundance) and environmental variables to map the areas likely to support the species and, hence, be potentially at risk of disease transmission (Kraemer et al., 2016; Rogers, 2006). Conversely, mechanistic models explicitly incorporate the biological and ecological processes underlying mosquito development and mortality across life stages, often implemented through differential equations to simulate population dynamics and disease transmission potential under varying climatic conditions (Guzzetta et al., 2016; Marini et al., 2017, 2019b; Poletti et al., 2011; Reuss et al., 2018; San Miguel et al., 2024; Wieser et al., 2019). These models require detailed life-history parameters, usually obtained from laboratory experiments or estimated from intensive field monitoring data. Both approaches have advantages and limitations, and both have been extensively applied to assess the potential impact of future environmental changes, such as climate change (Caminade et al., 2019; Cunze et al., 2016; Farooq et al., 2023; Fischer et al., 2011; Garrido Zornoza et al., 2024; Marini et al., 2019a; Tjaden et al., 2018).

However, even though some models have anticipated the spread of vector-borne diseases in temperate regions (Caminade et al., 2012; Cunze et al., 2016; Fischer et al., 2011; Schaffner et al., 2013), they often fall short in supporting real-world vector control programmes. Many models remain strictly academic and underutilised in public health practice, partly because they are developed by researchers in a top-down process and then offered to field practitioners and public health stakeholders with little or no co-development. Incorporation of public health stakeholders' practical perspectives regarding the spatio-temporal scales or operational constraints of public health interventions is thus missing (Braks et al., 2013; Leach and Scoones, 2013; Purse and Golding, 2015; Sedda et al., 2014). This disconnect can hinder the uptake of model outputs in operational decision-making, ultimately undermining the value of the modelling effort.

Here, we advocate for a bottom-up approach to *Aedes*-vector modelling that promotes early and sustained collaboration between modellers, entomologists, and public health professionals (Sedda et al., 2025). By building a shared conceptual framework and a common "operational taxonomy" of model terms, assumptions, and intended applications, we aim to bridge the gap between academic research and public health practice and to foster the co-development of modelling tools designed to predict the vector's spatio-temporal distribution and dynamics. Similar bottom-up approaches have successfully been used to co-develop dengue early warning systems, climate services, and vector-borne disease models, bringing together researchers from diverse disciplines (e.g., entomologists, parasitologists, biologists, geo-spatial specialists, statisticians, and modellers) with stakeholders from the public health sector (Stewart-Ibarra et al., 2019; Stewart-Ibarra et al., 2022).

To advance this goal, we convened a multidisciplinary expert workshop in Bologna, Italy, on 19–20 September 2024. The meeting brought together experts from the modelling community, medical entomology, and public health services to develop recommendations for increasing the relevance, interpretability, and practical application of predictive models in field settings. Through structured discussions and scenario-based analyses, participants identified actionable priorities for integrating modelling into public health strategies; the analysis presented in this paper is based on thematic synthesis of rapporteur summaries from those group discussions. Emphasis was placed on mutual learning and co-framing, highlighting how surveillance data can inform models and how models, in turn, can improve risk assessment and support timely vector and disease control measures.

2. Methods

The first “Climate-Sensitive Vector Dynamics Modelling Workshop”[1] was organised around the key phases of mosquito monitoring, surveillance, and disease prevention, with sessions explicitly structured to align quantitative modelling outputs with operational needs. A central objective was to improve the accessibility and interpretability of modelling frameworks for public health authorities (PHAs), who rely on predictive tools for risk assessment and intervention planning but may lack specialised training in modelling.

The workshop convened 45 participants from 13 countries, predominantly within Europe, with additional representation from the United States of America (Fig. SM1). Participants were affiliated with a broad range of institutions, including universities (n = 23), research institutes (n = 14), and regional, national, and international PHAs (n = 8). The group reflected a balanced disciplinary composition across modelling, medical entomology, and public health practice, and included 21 women and 24 men. A key characteristic of the group, relevant for interpreting the workshop outcomes, was that all participants were based in the non-native range of *Ae. albopictus*. Nevertheless, many participants maintain active collaborations with stakeholders in endemic countries where both *Ae. aegypti* and *Ae. albopictus* serve as primary disease vectors.

As a result, the discussions focused heavily on surveillance and risk prediction within Europe’s temperate and Mediterranean climates. In these regions, the establishment and ongoing spread of *Ae. albopictus* has shifted the epidemiological situation from sporadic, imported cases of *Aedes*-borne disease to a substantial increase of the likelihood of generation of local transmission starting from imported cases (Cattaneo et al., 2025; Menegale et al., 2025).

The two-day workshop opened with a series of oral presentations covering the state of the art in modelling *Ae. albopictus*' temporal dynamics and geographic distribution. On the second day, participants were assigned to five mixed discussion groups of 8–10 people each to reflect on and discuss the material presented previously. The group dimension and composition was deliberately designed to ensure disciplinary balance and promote integrative dialogue, with each group including representatives from epidemiological and ecological modelling, medical and field entomology, and public health practice. Efforts were also made to ensure diversity in institutional affiliations, professional seniority, and gender representation. Within each discussion group, a designated rapporteur documented the main arguments, areas of agreement and disagreement, and emerging recommendations. Rapporteurs’ summaries were subsequently compiled and reviewed in a plenary session to identify cross-cutting themes and areas of divergence. These summaries constituted the primary qualitative dataset used to inform the structure and content of this study.

Discussions in each group were guided by a structured set of thematic prompts designed to elicit perspectives on the challenges and opportunities for integrating predictive modelling into operational vector surveillance. The prompts covered eight themes:

1. feasibility of early warning systems for *Ae. albopictus* (Box 1);
2. key lessons learned from modelling and field experience;
3. data requirements, availability, and quality;
4. model definitions and terminology;
5. environmental complexity, including urban microclimates and climate-change adaptations;
6. standardisation and utility of diverse model outputs;
7. opportunities and barriers to data sharing;
8. willingness to contribute models or data to shared repositories.

The full list of questions is provided in Supplementary Table SM1.

A thematic content analysis was conducted on the collected summaries following a structured deductive–inductive approach. Predefined discussion themes, corresponding to the guiding prompts, served as the initial content coding framework. Each rapporteur’s summary was reviewed and coded against these themes, and the coded material was synthesised across groups. The analytical approach was inspired by well-established principles of thematic analysis (Braun and Clarke, 2006; Nowell et al., 2017), adapted to the exploratory and applied nature of a multidisciplinary workshop. The analysis aimed to identify cross-cutting issues, recurrent operational challenges, and areas of consensus rather than to generate a comprehensive qualitative typology. Coding was conducted independently by the lead author (FR) and subsequently consolidated by the last author (DDR) to ensure interpretative consistency. A summary table linking the overarching themes to the workshop questions is provided in Supplementary Table SM2. Given the nature and purpose of the workshop, the analysis reflects structured expert opinion rather than systematic qualitative saturation; however, the combination of guided prompts and cross-disciplinary participation provides a robust basis for identifying operational priorities.

3. Results and discussion

Participants consistently emphasised the critical importance of predictive modelling for *Ae. albopictus*, identifying it as one of the most urgent and complex challenges facing vector-borne disease prevention and preparedness in Europe. This perceived importance was driven by three main operational needs repeatedly highlighted across discussion groups: (i) the difficulty of anticipating seasonal population build-up under increasingly variable climatic conditions; (ii) the need to allocate limited surveillance and manage resources more efficiently; and (iii) the growing expectation that PHAs provide timely, evidence-based risk assessments despite sparse, heterogeneous, or unevenly distributed entomological data.

Addressing these challenges was widely viewed as requiring a genuinely multidisciplinary and cross-sectoral approach, integrating ecological modelling, vector ecology, climate science, epidemiology, and public health decision making and operations. This perspective aligns with the World Health Organisation’s call for “*strengthening basic and applied research, including predictive modelling, to improve vector control strategies and responses*” (World Health Organization, 2017). Since the workshop participants represented institutions ranging from municipal vector control units and regional public health services to national surveillance agencies, mosquito biology laboratories, and academic modelling groups, these results reflected the diversity of actors involved in risk assessment and early warning across operational scales. This diversity informed a shared recognition that effective modelling must bridge not only disciplinary boundaries, but also the practical

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[1] https://www.vectormodelling.com/Bologna2024/

constraints, decision-making processes, and timelines faced by public health stakeholders.

Through structured group discussions and thematic synthesis, seven cross-cutting domains emerged, capturing areas of broad consensus on current gaps, priorities, and opportunities for improving predictive modelling and its integration into routine surveillance and vector control workflows; these are presented in Sections 3.1 through 3.7.

3.1. Early warning needs and modelling use cases for public health

A central focus of the workshop was to define the types of predictions PHAs need to guide vector surveillance and intervention operations effectively. Participants stressed that PHAs primarily seek timely, location-specific information on when to start monitoring, how to schedule and spatially prioritise interventions, and when to conclude seasonal operations. Current practice in many municipalities, particularly in Italy, relies on broad seasonal cues and historical data (Da Re et al., 2024; Regione Emilia-Romagna, 2011). Models that predict the timing and magnitude of mosquito seasonality (onset, peaks, and offset) at sub-national spatial scale and sub-monthly temporal resolutions were considered valuable tools for refining and localising public health strategies (Box 1, Fig. 1).

Participants also explored whether models could help forecast the lag between egg detection and the onset of adult biting activity, a feature that could help PHAs to better time their intervention campaigns. Such predictions must account for interannual variability and climatological extremes, which modulate mosquito development and activity. For example, modelling studies on the potential introduction and establishment of *Ae. albopictus* in Belgium, a country currently located at the northernmost limit of the species European range, identified 2020 as particularly favourable for establishment (Da Re et al., 2025b).

From an operational point of view, forecasting lead time was a major concern. PHAs indicated that they need at least two weeks' notice to mobilise field teams and resources. In the Emilia-Romagna region of northern Italy, authorities typically plan to begin vector control interventions in April (calendar weeks 16–18; Carrieri et al., 2023; Da Re et al., 2024), seeking forecasts that can guide the timing and frequency of larviciding or source reduction campaigns, especially during key windows of mosquito activity.

A practical example was shared by one of the workshop participants, highlighting the use of an effective degree-day model developed to support early-season surveillance and focal control interventions of *Ae. albopictus* in the Netherlands. This correlative, easy to parametrise, model has proven valuable in identifying the timing of larval development onset and guiding local mosquito intervention strategies in areas where the species is currently spreading (Healy et al., 2019), enabling the Netherlands Food and Consumer Product Safety Authority (NVWA) to better plan surveillance and eradication campaigns. This example illustrates a broader point emphasised by one group during the workshop: "*it's not just about publishing a model, it's about showing its value in real-world decision-making*" (Leach and Scoones, 2013). In this sense, a practical case study performed in Spain, showed how ecological factors shaped mosquito population dynamics in urban environments, a critical step for developing effective management strategies against mosquito-borne diseases (Ferraguti et al., 2023). In collaboration with researchers from the Centro de Investigación Biomédica en Red (CIBER) and the Agència de Salut Pública de Barcelona (ASPB), a Spanish team analysed the effects of urban water infrastructure, climate conditions, and local management practices on mosquito occurrence in Barcelona (Ferraguti et al., 2023). Predictive models were constructed to map species distribution, revealing, for instance, that sandbox scuppers harboured mosquito larvae more frequently than siphonic or endless scuppers. Although larvicidal treatments effectively reduced larval populations, recolonisation typically occurred within 10–25 days. These findings directly informed a programme led by the ASPB to convert sandboxes into direct scuppers, highlighting the practical public health implications of the research (Ferraguti et al., 2023).

More broadly, the participants reiterated that model selection must be driven by the specific public health question rather than by disciplinary preference or data availability alone. Correlative approaches, including statistical and machine-learning models (Box 1), were seen as particularly well-suited for short-term, operational forecasting, where timely predictions of abundance, biting pressure, or imminent seasonal shifts are required to support resource allocation and intervention planning (Pennisi et al., 2026). In contrast, mechanistic models (Box 1 and Fig. 1) were considered more appropriate for strategic, long-term applications, such as exploring climate-change impacts, evaluating alternative and optimising data collection (Fesce et al., 2023), surveillance strategies, and the assessment of vector control interventions efficacy under different intervention scenarios (Fesce et al., 2025; Marini et al., 2019b). Modelling was also recognised as a valuable tool to communicate with the public about when and why specific intervention measures are implemented. In this sense, it was viewed not merely as a technical activity but as a tool for governance, planning, and public engagement.

Several participants noted that such models are already in practical use. For example, tools such as arbocartoR[2], which features an intuitive graphical user interface, have been applied retrospectively to quantify the effectiveness of vector control interventions, examining whether interventions altered indicators such as the duration of the biting season or the timing and magnitude of population peaks.

Despite these encouraging examples, the systematic integration of model outputs into routine public health decision-making remains limited, particularly in non-endemic settings. Most tools have been evaluated in research or retrospective contexts, and evidence of their prospective use by PHAs to directly inform operational decisions is still scarce. Even in countries already invaded by *Ae. albopictus*, where active monitoring programs are in place and model outputs may already be available, their incorporation into national plans remains limited. Although such integration could help tailor monitoring activities to environmental heterogeneity, this potential is often hindered by

Box 1

Model operational taxonomy.

Concept	Definition
Model	A model is a simplified quantitative representation of a system or phenomenon, developed to describe, explain, or predict outcomes. It uses mathematical or statistical methods to relate inputs to outputs and can range from purely data-driven formulations to process-based representations grounded in underlying mechanisms.
Mechanistic model	A mechanistic model represents a system, such as the dynamics of a mosquito population during the breeding season, by explicitly describing the underlying processes that generate the observed patterns. It uses biologically or physically meaningful parameters, which, in this case, may be temperature-dependent, and equations that represent different mosquito life stages to capture causal mechanisms.
Correlative model	A correlative model describes statistical associations between variables without assuming or explicitly specifying the processes that generate them. It identifies patterns, predictors, and relationships in the data but does not attempt to represent the causal mechanisms underlying those patterns.
Early warning	A forecasting tool or framework designed to provide information in advance about e.g. likely increases in mosquito abundance, biting pressure, or arboviral transmission risk. Early warning systems may integrate statistical, mechanistic, or hybrid models with real-time surveillance data and environmental predictors. Their primary purpose is operational: to support timely decisions on resource allocation, intensified surveillance, and (preventive) vector control measures.

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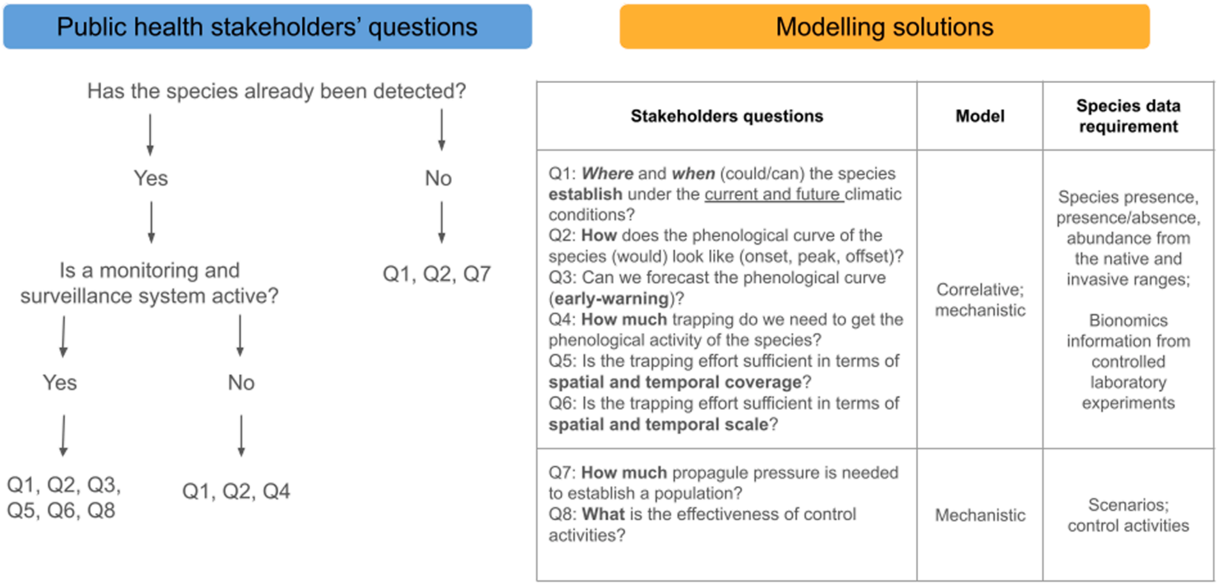
[2] https://www.arbocarto.fr/en/arbocartor



Stakeholders questions	Model	Species data requirement
Q1: ***Where*** and ***when*** (could/can) the species **establish** under the <u>current and future</u> climatic conditions? Q2: **How** does the phenological curve of the species (would) look like (onset, peak, offset)? Q3: Can we forecast the phenological curve **(early-warning)**? Q4: **How much** trapping do we need to get the phenological activity of the species? Q5: Is the trapping effort sufficient in terms of **spatial and temporal coverage**? Q6: Is the trapping effort sufficient in terms of **spatial and temporal scale**?	Correlative; mechanistic	Species presence, presence/absence, abundance from the native and invasive ranges; Bionomics information from controlled laboratory experiments
Q7: **How much** propagule pressure is needed to establish a population? Q8: **What** is the effectiveness of control activities?	Mechanistic	Scenarios; control activities

Fig. 1. Decision-relevant questions for modelling *Aedes albopictus* in non-native regions, and the corresponding modelling approaches and data needs. The flow diagram (left) summarises how modelling questions (Q) vary depending on detection status of the vector and the presence of a surveillance system. The right-hand table maps each question to the suitable model types and the required data sources.

insufficient dialogue among modellers, decision-makers, and PHAs. Fig. 1 outlines the decision-relevant questions that models should ultimately be able to address in non-endemic settings, from predicting seasonal phenology to evaluating the effectiveness of control activities, and can serve as a practical benchmark against which the operational readiness of existing tools should be assessed. A possible example is provided by the results of an ensemble model developed from ovitraps data collected nationwide in Italy and neighbouring countries (Da Re et al., 2025c). Outputs like the estimated local duration of vector activity in weeks, could help tailor vector monitoring and control activities to specific locations and periods of the year, thereby improving the efficiency of interventions, optimising the allocation of resources, and identifying areas where monitoring effort may be insufficient or excessive. The same modelling framework has been used to develop, in co-production with the Emilia-Romagna Region (Italy) PHAs, a regional passive surveillance system to estimate the weekly mosquito egg-laying activity in support of the standard *Ae. albopictus* surveillance (Blaha et al., 2026).

Importantly, participants emphasised that models should be assessed not only by technical accuracy but also by their added value over existing heuristics. If simple rules of thumb, such as assuming environmental conditions will mirror those of the previous year, perform equally well, the justification for using complex modelling approaches weakens. This aligns with Boden and McKendrick's ethical principles for delivering model-based evidence to public health stakeholders, indicating the importance of demonstrating benefits or added value of model outputs over existing information used to guide interventions (Boden and McKendrick, 2017).

Several discussions also addressed ethical and governance considerations. There was strong support for the co-production of modelling tools with PHAs, local communities, and other stakeholders to enhance trust, usability, and impact. Participants called for transparent delivery systems, adaptability to institutional turnover, and ethical frameworks guiding the use of predictive models by policymakers. Resources such as the "Model-Based Policymaking" framework (Boden and McKendrick, 2017) and recent literature on the co-production process in the One Health context (Asaaga et al., 2022; Purse et al., 2020) were cited as useful guidelines.

3.2. Perceived need for collaboration on shared purpose

The workshop underscored a broadly shared perception that, across the European countries represented, modelling, data generation and surveillance, and public health decision-making remain insufficiently connected. As one participant noted, this workshop felt like "*the first time, in my working experience, in which modellers, data contributors, and decision makers came together and worked as a community*." Across all discussion groups, there was a clear call to move beyond isolated technical efforts towards a systems-thinking approach grounded in mutual learning and iterative co-design. Such a shift was seen as essential for producing models that are mathematically sound, biologically interpretable, and operationally usable. However, the effective development and application of integrated models are often constrained by institutional fragmentation. In many European settings, vector modellers, entomological surveillance staff, and PHAs operate within separate funding streams, institutions and administrative levels, with limited coordination, thus hinder the outcome-based and co-production approach needed to align model outputs with decision-making needs.

A recurrent message across discussion groups was that effective modelling can only emerge when PHAs articulate clear operational questions, rather than when models are developed in isolation and later "pushed" toward decision makers. Participants stressed that priority-setting must originate with the agencies responsible for surveillance, outbreak preparedness, and resource allocation. Only once these priority questions are defined (e.g., *Where should traps be deployed? When should intensified surveillance begin? Which areas face the highest seasonal risk?*; Fig. 1), can modelling and data-collection strategies be meaningfully aligned. This reflects broader arguments in the public health modelling literature that emphasise the dialogue, rather than a one-way flow of information from modellers to decision makers responsible for vector control interventions (e.g., Leach and Scoones, 2013).

Within this broader need for co-produced objectives, participants noted that the absence of a standardised framework for collecting, reporting and analysing vector abundance and seasonal dynamics continues to limit the capacity to translate model outputs into operational guidance. Formalising collaboration between modellers, surveillance teams, and vector control operators within national vector plans was viewed as essential to overcome this barrier. A key first step in co-producing models for Public Health policy making is triangulating diverse operational priorities and knowledge across different actors in the wider public health stakeholder landscape, determining the specific questions related to their decision making that models can address, and the surveillance and data needed as inputs (Fig. 1, Leach and Scoones, 2013; Purse et al. 2020). Moreover, we recognise substantial heterogeneity across the wider public health stakeholder landscape with respect to the acceptance, development, and knowledge of modelling. Such heterogeneity will include jurisdictional and generational differences in training and exposure to modelling, which in turn lead to varying levels of understanding of modelling approaches and their perceived utility (Box. 1). This warrants explicit acknowledgement and constitutes an additional challenge for modellers, who should invest in the competencies and participatory methods required to engage public health stakeholders effectively throughout the modelling process.

A concrete illustration of how structured, risk-based decision frameworks can improve vector management comes from Italy's National Plan for Surveillance and Response to Arboviruses (PNA 2020–2025[3]). Although not directly derived from modelling, for the West Nile virus the plan classifies provinces (see NUTS-3 administrative units, i.e. sub-national regions defined by Eurostat, typically corresponding to provinces or comparable territorial divisions) into high, low, or minimal risk categories based on epidemiological evidence and ecological information from the previous seasons.

Participants suggested that applying similar principles to *Aedes* surveillance, integrating multidisciplinary data into a unified national framework, would support the selection of appropriate trap locations, refine temporal windows for surveillance, and ensure that resources are allocated where and when they have the greatest impact. In Italy, the PNA 2020–2025 includes provisions for the surveillance of *Aedes*-borne diseases, with a primary focus on immediate case reporting, timely epidemiological monitoring of human cases, risk communication, training of PHAs, and public awareness campaigns. However, monitoring of *Ae. albopictus*, while recommended, is not mandatory.

3.3. Need for a centralised operational platform

Across all discussion groups, participants strongly supported the creation of a centralised and sustained operational platform to host vector models, surveillance data, documentation, training materials, and real-world use cases at multiple spatial and operational scales. Both modellers and PHAs recognised this need, albeit for different reasons: modellers emphasised transparency, model comparison, and reproducibility, while PHAs highlighted the importance of accessible, interpretable tools to inform operational decisions under tight timelines. As one medical entomologist noted, "*We need a place where modellers, field staff, and health officials can all contribute and access what they need; it should be a living infrastructure.*"

Participants stressed that such a platform should go beyond static data aggregation, and function instead as a dynamic environment for model validation, interdisciplinary collaboration, and long-term technical support, ensuring continuity across projects and institutions. Several groups emphasised the need for dual-format outputs: simplified, public-facing visualisations to support awareness and communication, and detailed technical dashboards providing weekly risk maps and quantitative thresholds to guide public health decision-making. This dual approach was considered essential for ensuring that models are scientifically robust and practically usable. "*We need to prove the value of modelling with real, demonstrable use cases*," one group stated, noting that these demonstrations should highlight not only successes but also failures, as documenting where models underperform is as critical for refinement as showcasing their achievements in designing national or regional intervention plans.

Public-facing visualisations were also seen as essential for public education and awareness. From the perspective of health authorities, such interfaces can be used in communication campaigns aimed at informing citizens about the risks associated with *Aedes*-borne diseases and, more broadly, promoting good practices to prevent mosquito infestations during high-risk periods in high-risk areas.

The VEClim[4] initiative was frequently cited as a promising prototype. The platform currently hosts dynamical models assessing climatic suitability and seasonal risk for *Ae. albopictus* and phlebotomine sand flies (Erguler et al., 2024). Planned developments include integrating a broader suite of modelling tools, implementing ensemble approaches, and providing an interactive web interface that allows users to explore short- and long-term predictions, adjust key parameters, and run alternative forecasting scenarios. Another interesting initiative is the platform BayByeMos[5], developed by the University of Bayreuth (Germany) and providing West Nile virus risk assessment for Germany at NUTS3 regions based on the mechanistic model developed by Mbaoma et al. (2024).

These features were seen as valuable for both operational planning and for public communication, for instance by illustrating expected seasonal peaks and encouraging private-garden interventions in areas with limited municipal coverage.

Participants also mentioned complementary initiatives such as the IDAlert[6], e4warning[7] and CLIMOS[8] projects, all aiming to develop forecasting systems and integrated platforms to improve Europe's resilience to climate-sensitive infectious diseases. These examples reinforced the view that a centralised, well-maintained platform for vector modelling is both feasible and increasingly necessary.

Despite broad enthusiasm for a centralised platform, participants stressed that long-term sustainability remains a major unresolved challenge. Many existing tools originate from fixed-term research projects, but maintaining an operational platform requires ongoing activities (routine model updates, integration of new data streams, server maintenance, bug fixing, interface improvements) that are fundamentally IT and service-oriented tasks rather than research outputs. These activities fall outside traditional academic mandates and funding structures. Without dedicated, recurrent funding and clear institutional ownership, even well-designed platforms risk becoming outdated or non-functional after the project cycle ends. Sustainable implementation therefore requires identifying organisations (national PHAs, EU-level bodies like the Copernicus Health Hub[9], or dedicated operational centres) willing and able to assume long-term responsibility for platform maintenance, governance, and user support. The absence of such a structure was considered a key barrier to making these systems genuinely operational rather than remaining prototypes or proof-of-concept tools.

To address these challenges, participants highlighted the need for hybrid governance and funding arrangements that combine scientific oversight with operational stewardship. Several options were proposed: i) embedding platform maintenance within national or regional PHAs that already manage long-term surveillance infrastructures (such as health reporting systems) and could integrate model updates into existing workflows; ii) establishing European-level coordination through bodies such as the European Centre for Disease Prevention and Control (ECDC), the European Food Safety Authority (EFSA) or a consortium of national institutes to provide shared governance, stable funding, and centralised technical support; iii) forming public–academic-private partnership in which universities or research institutes drive methodological innovation, while operational private partners host, maintain, and update the platform. Participants agreed that

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[3] https://www.salute.gov.it/imgs/C_17_pubblicazioni_2947_allegato.pdf

[4] https://veclim.com

[5] https://www.bayceer.uni-bayreuth.de/BayByeMos/riskmaps/wnv/

[6] https://idalertproject.eu/

[7] https://www.e4warning.eu/

[8] https://climos-project.eu/

[9] https://health.hub.copernicus.eu/

whichever option is chosen, clear institutional ownership, recurrent funding, and defined maintenance responsibilities are essential to prevent operational decay and ensure the platform remains reliable, up to date, and genuinely usable for public health decision-making.

3.4. Communication: the need for an operational taxonomy

Beyond the technical aspects of model development, participants emphasised the need for clearer and more consistent language when discussing predictive modelling for *Ae. albopictus*. The workshop underscored the absence of a shared "operational taxonomy" (Box 1), with several participants remarking that *"we don't even have a common definition of what the output of a predictive model is*." This lack of common terminology complicates communication between modellers, surveillance teams, and public health stakeholders.

These challenges reflect deeper differences in how various communities and scientific disciplines conceptualise models. A key reason for this conceptual ambiguity is that different modelling approaches serve fundamentally different purposes. For example, mechanistic models are typically built around explicit biological processes and allow the exploration of alternative scenarios, whereas correlative approaches identify statistical relationships that are often perceived as better suited for rapid forecasting (Box 1). Both approaches have legitimate and complementary roles, but without shared definitions and indicators of performance, it becomes difficult for stakeholders to assess what evidence a model can, or cannot, provide, or at which stage of surveillance and interventions a particular approach is most appropriate.

From an operational perspective, these modelling approaches cannot be collapsed into a single definition without obscuring important differences in assumptions, outputs, and intended use. Participants therefore agreed on the need to develop a shared operational taxonomy that clearly articulates the types of models available, the questions they can address, the data they require, and the assumptions underpinning them. Such a framework could draw heavily from established precedents in ecology and Species Distribution Modelling literature, where similar classification challenges have been extensively debated (Araújo et al., 2019; Sillero et al., 2021; Zurell et al., 2020).

In practical terms, such a taxonomy would help classify models according to:

1. The decision context they are designed to inform (e.g., early warning, resource allocation, strategic planning);
2. The type of evidence they produce (e.g., forecasts, scenarios, risk maps, uncertainty ranges);
3. The data requirements and limitations: identify when a model is being pushed beyond its "knowledge base." This occurs in both modelling approaches: correlative models may lack occurrence data for extreme climates, while mechanistic models may lack life-history trait data for temperatures outside of laboratory-tested ranges, as well as for other abiotic factors such as water availability. In both cases, if the environmental gradients are not fully covered by the input data, the resulting predictions in undersampled areas are based on extrapolation rather than evidence. Highlighting these data gaps is essential for users to recognise when predictions in undersampled areas or at the edges of the species' geographic range are based on mathematical assumptions rather than empirical evidence;
4. The degree of interpretability for public health stakeholders.

Such a taxonomy would improve communication across disciplines, promote transparency, and help ensure that models are interpreted and used appropriately within operational workflows. Box 1 represents a first step toward articulating this shared terminology, offering a preliminary framework to support dialogue between modellers and public health stakeholders. Together with Fig. 1, which outlines how different model types align with surveillance and decision-making needs, these elements aim to provide initial guidance for building a more coherent, standardised, and operationally relevant modelling vocabulary.

3.5. Spatial scale mismatch and local relevance

Participants emphasised that PHAs require operationally relevant lead times (1–4 weeks), neighbourhood-scale spatial resolution, and at least weekly temporal granularity to guide interventions such as triggering larvicide campaigns, prioritising hotspot inspections, or planning door-to-door control interventions. In contrast, many existing models operate at coarser spatial and temporal scales.

Biogeographical models often rely on multi-decadal climatic averages and coarse environmental grids (commonly 1 km^2 or larger). While appropriate for broad-scale analyses, these coarse scales limit utility for decisions depending on short-term fluctuations and local microclimates. Furthermore, the reliance on data aggregated at coarse administrative levels introduces significant technical bias; the use of centroid-based inputs from large spatial units can distort environmental values and artificially inflate predicted ranges, a phenomenon that degrades model performance regardless of the underlying environmental grain size (Cheng et al., 2021). Consequently, transitioning to finer resolutions is not merely a matter of detail, but a necessity for ensuring the empirical validity of models that depend on short-term fluctuations, local environmental conditions, and topographically complex areas (Malle et al., 2025).

This disparity underscores the need for locally validated, small-area models that reflect the heterogeneity driving mosquito dynamics, including microclimatic variation, fine-scale hydrology (e.g., rainfall effects on aquatic stages), vegetation structure (adult resting sites), and socio-environmental conditions. Participants noted that such models could be nested within broader regional or national frameworks, achieving methodological consistency while retaining local interpretability.

3.6. Over-reliance on coarse climate predictors

Participants noted that many current models rely heavily on macroclimatic variables, often derived from coarse-resolution climate grids or multi-decadal averages, which limits their ability to capture the environmental heterogeneity that shapes mosquito dynamics in urban settings. While temperature and precipitation remain essential components, they are insufficient on their own for forecasting fine-scale patterns or informing targeted interventions.

A recurring point was the need to incorporate urban-specific drivers that strongly modulate *Ae. albopictus* abundance, including irrigation practices, container availability, land use, vegetation structure, microclimatic conditions, and human behaviour. Several participants highlighted the value of emerging high-resolution environmental datasets, such as the downscaled Land Surface Temperature products from the European Space Agency Climate Change Initiative (CCI) EO4UrbanClimate[10], which provide calibrated urban temperature data at 30 m resolution. They also noted regional datasets like the European Joint Research Centre-EMO (Salamon et al., 2026). Integrating such data could substantially improve model realism in cities, where microclimates and human-modified environments strongly influence mosquito ecology.

Participants also stressed that biologically meaningful variables are often under-represented. For instance, the effects of rainfall on mosquito population dynamics remain poorly studied (e.g. (Alto and Juliano, 2001; Dieng et al., 2012; Kern et al., 2026). While intuitively important, participants noted the complexity of interpreting rainfall effects due to the confounding impacts of man-made irrigation, drought, and flooding. Drought conditions may enhance transmission risk by increasing water

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[10] https://climate.esa.int/en/supporting-the-paris-agreement/eo4urbanclimate/

storage and human–mosquito contact, while excessive rainfall may flush larvae. These insights echoed presentations calling for the development of controlled laboratory experiments to better understand the impact of water availability on the aquatic life stages of *Ae. albopictus*. The impact of diurnal temperature range on mosquito development and biting behaviour was discussed, alongside the potential influence of light pollution on diapause. One oral presentation noted shifts in *Ae. aegypti* biting activity in Bangladesh under changing climate conditions (Bashar et al., 2020). Another modelling study from Emilia-Romagna showed improved predictive performance when using minimum daily temperature (Angelini et al., 2023) instead of daily mean temperature values to model *Ae. albopictus* egg dynamics. The model by Brass et al. (2024) was cited as exemplary for incorporating adult female size structure, this factor being strongly associated with arbovirus transmission risk.

Across discussions, participants cautioned against "over-modelling", i.e., building increasingly complex frameworks without clear biological grounding or operational value (Da Re et al., 2024). Greater parsimony, transparent assumptions, and stringent local validation were consistently identified as essential for producing models that remain interpretable and genuinely useful for public health applications. However, participants repeatedly emphasised that even the most refined environmental and biological predictors cannot be meaningfully integrated into operational models without a strong surveillance foundation. Reliable fine-scale modelling ultimately depends on dense, long-term surveillance networks capable of capturing neighbourhood-level variation and interannual dynamics of mosquito field populations. Local validation using extensive ovitrap datasets, such as those available in parts of Switzerland or the Emilia-Romagna region (Italy) (Da Re et al., 2024), was highlighted as essential for calibrating model parameters, assessing predictive skill, and identifying early deviations from expected seasonal patterns. Without robust time series of ovitrap, adult trap, breeding site, and intervention data at fine spatial resolution, models cannot generate actionable short-term forecasts or support timely operational decisions.

In this sense, model development and surveillance capacity are mutually dependent: environmental and biological insights require empirical grounding, and empirical patterns gain operational value only when translated through well-validated models (Restif et al., 2012). Without robust surveillance underpinning, models cannot achieve the local reliability or predictive power needed for public health decision-making. This issue is explored further in the following section.

3.7. Quality of entomological data

The limitations described above, mismatched spatial scales and insufficient representation of key ecological drivers ultimately converge on a common constraint: the availability of robust, consistent, and long-term surveillance data. Participants emphasised that entomological surveillance is the empirical backbone of any predictive modelling effort and strongly shapes what models can, or cannot, achieve.

Ovitraps remain the most widely used tool for *Ae. albopictus* surveillance in Europe. These simple water-filled containers, equipped with a substrate for egg laying, provide cost-effective information on species presence, early seasonal emergence, and the timing of the first adult population peak, signals that are often used operationally to plan larvicide campaigns or anticipate nuisance peaks (Carrieri et al., 2012). However, participants highlighted important limitations: ovitraps offer only partial insight into population abundance, are sensitive to placement heterogeneity, and frequently lack species-level resolution, especially in those areas where multiple artificial container-breeding mosquitoes co-occur (e.g., *Ae. albopictus* vs. *Ae. japonicus* or *Ae. koreicus*; Anicic et al., 2023). Developing protocols aimed at standardising trap placement, sampling frequency, and spatial coverage was seen as essential. The AIMSURV monitoring programme (2020–2021; Miranda et al., 2022) serves as a key precedent for such efforts; by specifying sampling levels and standardising techniques, it was successfully implemented by 42 European teams, suggesting that the uptake of a simplified set of recommendations can be widespread if sufficient effort is made to engage a broad network of participants.

Beyond data quality, data accessibility emerged as a major bottleneck. Participants stressed the need for interoperable, standardised datasets that can be shared across institutions and modelling groups. While initiatives such as VectAbundance (Da Re et al., 2024), VecDyn (Rund et al., 2023), and VectorNet (Wint et al., 2023) are vital for harmonizing entomological abundance data and training correlative models, a critical requirement is the availability of high-quality trait-based frameworks necessary to inform mechanistic models. Developing these frameworks hinges on experimentally derived vector trait data, such as development rates and longevity, that capture biological mechanisms underpinning transmission. However, the reliability of these models is often hampered by inconsistent terminology and insufficient detail in data sharing, which leads to information loss and prohibits analytical comprehensiveness across studies. To address this, emerging standards such as MIReVTD (Minimum Information for Reporting Vector Trait Data; Ryan et al., 2025) provide essential reporting checklists that balance completeness with ease of use for data generators. By adopting such standards, biological data from repositories like VecTraits (Johnson et al., 2023) and specific datasets such as AedesTraits (Da Re et al., 2025a) can be more effectively integrated with the longitudinal abundance data provided by the aforementioned initiatives. This alignment between data infrastructure and reporting standards allows for the robust calibration of mechanistic models grounded in high-quality, reusable evidence rather than fragmented observations.

The discussion also highlighted the example of VectorBase (Giraldo-Calderón et al., 2015), historically one of the primary bioinformatic resources for vector genomics and phenotypic datasets of disease vectors. As pointed out in Section 3.3, long-term sustainability is essential also for data storage and accessibility. VectorBase's recent funding instability (Christophides, 2024) underscored the vulnerability of large data platforms that rely on short-term grants rather than structural public-health funding.

In countries without regular endemic transmission, including Italy, surveillance of *Aedes* species remains recommended but not mandated, and implementation is highly variable. Under the PNA 2020–2025, hotspot-focused monitoring using ovitraps and/or BG-Sentinel traps is encouraged, but municipalities face substantial logistical and economic barriers. In settings without viral circulation, *Ae. albopictus* is often perceived primarily as a biting nuisance species, limiting investment in maintaining a permanent monitoring system.

Participants also discussed the expanding role of citizen science (CS). Platforms such as Mosquito Alert (Spain) (Palmer et al., 2017), ZanzaMapp (Italy) (Caputo et al., 2020), and Mückenatlas (Germany) (Walther and Kampen, 2017) have broadened spatial coverage and proved valuable for public engagement and early detection, particularly of new invasive species outside formal surveillance zones (Eritja et al., 2019). However, participants stressed significant challenges for predictive modelling: CS data are subject to strong sampling biases (population density and structure, smartphone access, user engagement), variable temporal resolution, and often incomplete metadata. Without rigorous data cleaning, bias detection and correction (Padilla-Pozo et al., 2024), and expert verification, such datasets risk propagating errors into model calibration or validation. As one public health expert remarked, "*You can collect a lot through citizen science, but turning it into something predictive and reliable is a completely different task*."

Across the workshop, there was strong consensus that sustained investment in high-quality, harmonised surveillance/monitoring networks is indispensable. Without reliable, long-term, and spatially resolved entomological data, efforts to develop fine-scale models, incorporate urban predictors, or build operational early warning systems will remain severely constrained. It is important to encourage sharing both input data and model outputs, to make sure that data providers get some advantage from sharing their data, and to ensure that analyses are transboundary wherever possible.

4. Conclusions

Aligning with recent assessments by Brown et al. (2025) and Sedda et al. (2025), our workshop highlights a persistent "implementation gap": the difficulty of transforming high-potential predictive models into timely, trusted, and operationally relevant tools. Findings suggest the field needs a shift from a "supply-driven" scientific approach to a "demand-driven" operational framework (Box 2) built on the following four pillars.

1. Structural alignment

As remarked also by Sedda et al. (2025), the lack of centralised guidelines and the structural differences between agencies create significant uncertainty for public health managers. To be effective, models must be adapted to the local or more extensive scales where interventions take place, ensuring that the information meets the needs of the end-users, also known as operational salience (Cash et al., 2003; Jebeile, 2024).

Efforts to make predictive models more accessible and operationally relevant inevitably trigger a “cascade of uncertainty” (Wilby and Dessai, 2010). This uncertainty must be explicitly acknowledged and managed through transparent communication and close engagement with end users instead of being seen as a limitation. At the same time, improving operational usability requires greater attention to the form in which model outputs are delivered. Simplifying outputs and converging on a limited set of shared, decision-facing metrics would allow diverse modelling approaches to contribute coherently to public health implementation (e.g. season onset, peak, and offset for mosquitoes). Explicitly articulating what quantitative information different models provide, and how these outputs can support surveillance, is therefore essential for ensuring their practical value.

Box 2
Perspective and future engagement.

Theme	Key Messages
Implementation, Governance & Co-Production	• Cross-sectoral collaboration is essential across modelling, entomology, public health, and affected communities. • Co-production, not isolated consultation, is the basis of trusted, usable modelling. • Models must align with institutional decision cycles (e.g., seasonal planning, weekly vector control rounds). • Public-facing outputs must communicate information, not raw data, and be aligned with community needs and perceptions. • Modellers should invest in the competencies required to engage public health stakeholders effectively throughout the modelling process.
Infrastructure & Platforms	• A centralised, sustained, open platform is essential for hosting models, surveillance data, model training, and documentation. • VEClim, VectorNet, and the Vector Modelling Workshop portals should be expanded and linked. • Long-term sustainability requires stable governance, recurrent funding, and institutional ownership (not short-term research grants).
Science & Evidence-based Practice	• Key drivers need better representation: urban microclimates, fine-scale hydrology, behavioural ecology, vegetation structure, and control operations. • Evidence for biologically meaningful predictors is fragmented; systematic reviews, meta-analyses, and targeted experiments are required. • Model outputs must reflect user needs: neighbourhood-scale granularity, short (1–4 week) lead times, and clear, actionable indicators. • Avoid over-modelling—prioritise parsimony, interpretability, and biological realism.
Surveillance & Data Quality	• Surveillance remains the limiting factor for model development, calibration, and validation. • Dense, long-term, harmonised datasets are essential for neighbourhood-level analyses and interannual variability. • Models and surveillance are mutually dependent: surveillance provides empirical grounding, models give surveillance operational meaning. • Field validation and data quality assurance are critical before informing interventions.

2. Collaborative data infrastructure

The advancement of epidemic intelligence relies on the modernisation of data infrastructures that support modelling, surveillance, and decision-making. As highlighted by van Kleef et al. (2025), this requires coordinated progress across several dimensions:

- Common data standards, to ensure interoperability and comparability across datasets, models, and jurisdictions;
- Open science practices, fostering shared code, transparent workflows, and rapid validation; and
- Capacity building, to address the limited resources and modelling capabilities that continue to constrain many local PHAs (Sedda et al., 2025).

3. Strengthening the empirical basis

Models must incorporate biologically meaningful drivers that are currently underrepresented, such as microclimatic heterogeneity, and mosquito age structure. Equally important is that stakeholder-driven questions are framed in biologically plausible terms, so that operational needs align with ecological and entomological realities. Consolidating this knowledge through systematic reviews and targeted experimental studies is therefore a priority to ensure that integrated surveillance is built on robust empirical evidence.

4. Multisectoral integration

Modelling is as much a social and political process as a mathematical one. Moving beyond the “extractive” forms of engagement described by Leach and Scoones (2013) therefore, requires the adoption of multisectoral approaches. As defined by the World Health Organization (2020) and reaffirmed for vector-borne disease prevention by Nunes et al. (2025), Multisectoral Approaches recognise that effective action depends on coordinated engagement across health, environmental, and planning sectors. This entails breaking down traditional silos by involving interconnected actors such as ecologists, environmental management authorities, and urban planners. At the same time, effective collaboration places new demands on modellers, who must develop the communication and engagement skills needed to work productively with public health professionals (Sedda et al., 2025). Finally, integration requires institutional frameworks that support co-production and embed modelling tools within existing decision-making processes, as proposed by Díaz et al. (2024).

Ultimately, technical sophistication is insufficient without institutional legitimacy and political coordination. Effective surveillance and control require strong organisational bases and a clear recognition of the value of community engagement. Surveillance and modelling must evolve in tandem: the former provides the empirical foundation, while the latter offers the foresight needed for proactive health protection. By placing sustained multisectoral collaboration at the centre, the modelling community can transform theoretical insights into real-world interventions.

It should also be noted that the priorities identified here primarily reflect the perspectives of experts operating in non-endemic, temperate European settings, where the central challenge is not forecasting outbreak intensity from regular seasonal transmission, but rather detecting and anticipating the establishment and spread of an invasive vector, and guiding the timing of control interventions based on vector seasonal dynamics. Transferring these priorities to endemic settings in which *Ae. aegypti* and *Ae. albopictus* co-occur and surveillance infrastructure may differ substantially, would therefore require careful adaptation. Moreover, outbreak forecasting in non-endemic settings faces a distinct and additional challenge: autochthonous transmission events have historically been rare and sporadic, meaning that models cannot yet be trained and validated on long time series of local outbreaks. Retrospective analysis of dengue and chikungunya transmission in Italy from 2006 to 2023 identified only six local outbreaks, with both their timing and location driven primarily by the incidental importation of viraemic cases rather than by spatially heterogeneous local transmission risk (Menegale et al., 2025). This implies that many areas with similar ecological suitability remain undetected as potential outbreak sites simply because importation has not yet occurred there.

Nonetheless, bottom-up co-development approaches applied in endemic regions, such as those documented by Stewart-Ibarra et al. (2019, 2022) in the Caribbean, reveal a partially overlapping set of structural challenges: stakeholders similarly identified fragmented communication between climate scientists, modellers, and public health stakeholders, and stressed the need for co-learning and sustained partnerships across institutional and disciplinary silos. This comparison suggests that while the barriers to model co-development may be broadly shared, the specific modelling needs, data requirements, and decision timescales are highly context-dependent and should be defined locally.

Declaration of generative AI use

During the preparation of this work, Daniele Da Re used ChatGPT 5.1 to check the grammatical consistency and flow of the text of the first draft. After using this tool, all the authors reviewed and edited the content as needed and took full responsibility for the content of the published article.

Ethics approval and consent to participate

Participation in the workshop was voluntary. No personal identifying data was collected, subsequently ethics approval was not needed.

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. Views and opinions expressed in this manuscript are those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them. The views expressed are the ones of Olivier Briet and do not represent ECDC's official position.

CRediT authorship contribution statement

Federico Romiti: Writing – review & editing, Writing – original draft, Formal analysis. **Sarah Droghei:** Writing – review & editing, Writing – original draft. **Dominic Brass:** Writing – review & editing, Writing – original draft. **Cyril Caminade:** Writing – review & editing, Writing – original draft. **Giovanni Marini:** Writing – review & editing, Writing – original draft. **Bethan Purse:** Writing – review & editing, Writing – original draft. **Kamil Erguler:** Writing – review & editing, Writing – original draft. **Alessandro Albieri:** Writing – review & editing. **Paola Angelini:** Writing – review & editing. **Margo Blaha:** Writing – review & editing. **Olivier Briet:** Writing – review & editing. **Mattia Calzolari:** Writing – review & editing. **Marco Carrieri:** Writing – review & editing. **Silvio D'Alessio:** Writing – review & editing. **Martina Ferraguti:** Writing – review & editing. **Nicola Ferrari:** Writing – review & editing. **Elisa Fesce:** Writing – review & editing. **Eleonora Flacio:** Writing – review & editing. **Miguel Garrido Zornoza:** Writing – review & editing. **Pachka Hammami:** Writing – review & editing. **Paul J Huxley:** Writing – review & editing. **Adolfo Ibanez-Justicia:** Writing – review & editing. **Carla Ippoliti:** Writing – review & editing. **Emmanuelle Kern:** Writing – review & editing. **Eleonora Longo:** Writing – review & editing. **Alexander Meyer:** Writing – review & editing. **Ruth Müller:** Writing – review & editing. **Marta Pardo:** Writing – review & editing. **Friederike Reuss:** Writing – review & editing. **Greta Santarelli:** Writing – review & editing. **Lukas Sprengers:** Writing – review & editing. **Stephanie Margarete Thomas:** Writing – review & editing. **Wim Van Bortel:** Writing – review & editing. **Chiara Virgilito:** Writing – review & editing. **Yiran Wang:** Writing – review & editing. **William Wint:** Writing – review & editing. **Roberto Rosà:** Writing – review & editing, Writing – original draft, Conceptualization. **Daniele Da Re:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization.

Declaration of competing interest

The Authors have no conflicts of interest to declare. The authors alone are responsible for the views expressed in this manuscript and do not necessarily represent the views, decisions or policies of the institutions with which they are affiliated.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.actatropica.2026.108108.

Data availability

No data was used for the research described in the article.

References

Ahmed, D.A., Hudgins, E.J., Cuthbert, R.N., Kourantidou, M., Diagne, C., Haubrock, P.J., Leung, B., Liu, C., Leroy, B., Petrovskii, S., Beidas, A., Courchamp, F., 2022. Managing biological invasions: the cost of inaction. Biol. Invasions 24, 1927–1946. https://doi.org/10.1007/s10530-022-02755-0.

Alto, B.W., Juliano, S.A., 2001. Precipitation and temperature effects on populations of *Aedes albopictus* (Diptera: Culicidae): implications for range expansion. J. Med. Entomol. 38, 646–656. https://doi.org/10.1603/0022-2585-38.5.646.

Amraoui, F., Vazeille, M., Failloux, A.B., 2016. French Aedes albopictus are able to transmit yellow fever virus. Eurosurveillance 21. https://doi.org/10.2807/1560-7917.ES.2016.21.39.30361.

Angelini, P., Monti, M., Albieri, A., Antolini, G., Carrieri, M., 2023. Analisi della serie storica dei dati di monitoraggio di Aedes albopictus in Emilia-Romagna e possibili correlazioni con il cambiamento climatico. In: Presented at the XLVII Convegno dell'Associazione Italiana di Epidemiologia, p. 296.

Anicic, N., Steigmiller, K., Renaux, C., Ravasi, D., Tanadini, M., Flacio, E., 2023. Optical recognition of the eggs of four Aedine mosquito species (Aedes albopictus, Aedes geniculatus, Aedes japonicus, and Aedes koreicus). In: *Plos one*, 18, e0293568.

Araújo, M.B., Anderson, R.P., Márcia Barbosa, A., Beale, C.M., Dormann, C.F., Early, R., Garcia, R.A., Guisan, A., Maiorano, L., Naimi, B., O'Hara, R.B., Zimmermann, N.E., Rahbek, C., 2019. Standards for distribution models in biodiversity assessments. Sci. Adv. 5, eaat4858. https://doi.org/10.1126/sciadv.aat4858.

Asaaga, F.A., Young, J.C., Srinivas, P.N., Seshadri, T., Oommen, M.A., Rahman, M., Kiran, S.K., Kasabi, G.S., Narayanaswamy, D., Schäfer, S.M., Burthe, S.J., August, T., Logie, M., Chanda, M.M., Hoti, S.L., Vanak, A.T., Purse, B.V., 2022. Co-production of knowledge as part of a OneHealth approach to better control zoonotic diseases. PLOS Glob. Public Health 2, e0000075. https://doi.org/10.1371/journal.pgph.0000075.

Bashar, K., Sarker, A., Asasuzzaman, Rahman, M.S., Howlader, A.J., 2020. Host preference and nocturnal biting activity of mosquitoes collected in Dhaka. Bangladesh. Int. J. Mosq. Res. 7, 01–08.

Battistin, G., Franceschini, A., Paoli, F., Lencioni, V., 2024. Colonization by tiger mosquito (Aedes albopictus Skuse, 1894) of mountain areas over 600 m above sea level in the surroundings of Trento city, Northeast Italy. J. Entomol. Acarol. Res. 56. https://doi.org/10.4081/jear.2024.12185.

Blaha, M., Albieri, A., Angelini, P., Antolini, G., Bonannella, C., Laurini, F., Rosà, R., Da Re, D., 2026. Development and implementation of a passive surveillance system for *Aedes albopictus* in Emilia-Romagna, Italy. Ecol. Inf., 103718 https://doi.org/10.1016/j.ecoinf.2026.103718.

Boden, L.A., McKendrick, I.J., 2017. Model-Based Policymaking: A Framework to Promote Ethical "Good Practice" in Mathematical Modeling for Public Health Policymaking. Front. Public Health 5. https://doi.org/10.3389/fpubh.2017.00068.

Braks, M., Van Ginkel, R., Wint, W., Sedda, L., Sprong, H., 2013. Climate change and public health policy: translating the science. IJERPH 11, 13–29. https://doi.org/10.3390/ijerph110100013.

Brass, D.P., Cobbold, C.A., Purse, B.V., Ewing, D.A., Callaghan, A., White, S.M., 2024. Role of vector phenotypic plasticity in disease transmission as illustrated by the spread of dengue virus by Aedes albopictus. Nat. Commun. 15, 7823. https://doi.org/10.1038/s41467-024-52144-5.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101. https://doi.org/10.1191/1478088706qp063oa.

Brown, H.E., Wrench, E., Wolfe, K., Moore, T.C., Tangena, J.A., Sedda, L., 2025. Collaborative engagement with vector control stakeholders is key to enhance the utility of vector-borne disease models. Parasites Vectors 18, 143. https://doi.org/10.1186/s13071-025-06751-w.

Brustolin, M., Bartholomeeusen, K., Rezende, T., Ariën, K.K., Müller, R., 2024. Mayaro virus, a potential threat for Europe: vector competence of autochthonous vector species. Parasites Vectors 17, 200. https://doi.org/10.1186/s13071-024-06293-7.

Caminade, C., Medlock, J.M., Ducheyne, E., McIntyre, K.M., Leach, S., Baylis, M., Morse, A.P., 2012. Suitability of European climate for the Asian tiger mosquito *Aedes albopictus* : recent trends and future scenarios. J. R. Soc. Interface 9, 2708–2717. https://doi.org/10.1098/rsif.2012.0138.

Caminade, C., McIntyre, K.M., Jones, A.E., 2019. Impact of recent and future climate change on vector-borne diseases. Ann. N. Y. Acad. Sci. 1436, 157–173. https://doi.org/10.1111/nyas.13950.

Caputo, B., Manica, M., Filipponi, F., Blangiardo, M., Cobre, P., Delucchi, L., De Marco, C.M., Iesu, L., Morano, P., Petrella, V., Salvemini, M., Bianchi, C., Della Torre, A., 2020. ZanzaMapp: A scalable citizen science tool to monitor perception of mosquito abundance and nuisance in Italy and beyond. IJERPH 17, 7872. https://doi.org/10.3390/ijerph17217872.

Carrieri, M., Angelini, P., Venturelli, C., Maccagnani, B., Bellini, R., 2012. Aedes albopictus (Diptera: Culicidae) population size survey in the 2007 Chikungunya outbreak area in Italy. II: estimating epidemic thresholds. Jnl. Med. Entom. 49, 388–399. https://doi.org/10.1603/ME10259.

Carrieri, M., Albieri, A., Angelini, P., Soracase, M., Dottori, M., Antolini, G., Bellini, R., 2023. Effects of the weather on the seasonal population trend of Aedes albopictus (Diptera: Culicidae) in Northern Italy. Insects 14, 879. https://doi.org/10.3390/insects14110879.

Cash, D., Clark, W.C., Alcock, F., Dickson, N., Eckley, N., Jager, J., 2003. Salience, credibility, legitimacy and boundaries: linking research, assessment and decision making. SSRN J. https://doi.org/10.2139/ssrn.372280.

Cattaneo, P., Salvador, E., Manica, M., Barzon, L., Castilletti, C., Di Gennaro, F., Huits, R., Merler, S., Poletti, P., Riccardo, F., Saracino, A., Segala, F., Zammarchi, L., Buonfrate, D., Gobbi, F., 2025. Transmission of autochthonous Aedes-borne arboviruses and related public health challenges in Europe 2007–2023: a systematic review and secondary analysis. Lancet Reg. Health - Eur. 51, 101231. https://doi.org/10.1016/j.lanepe.2025.101231.

Cheng, Y., Tjaden, N.B., Jaeschke, A., Thomas, S.M., Beierkuhnlein, C., 2021. Using centroids of spatial units in ecological niche modelling: Effects on model performance in the context of environmental data grain size. Glob. Ecol. Biogeogr. 30, 611–621. https://doi.org/10.1111/geb.13240.

Christophides, G.K., 2024. Essential vector-disease resource faces shutdown without funding. Nature 634 (8032), 33.

Clements, A.N., Harbach, R.E., 2017. History of the discovery of the mode of transmission of yellow fever virus. J. Vector Ecol. 42, 208–222. https://doi.org/10.1111/jvec.12261.

Cunze, S., Kochmann, J., Koch, L.K., Klimpel, S., 2016. Aedes albopictus and its environmental limits in Europe. PLOS ONE 11, e0162116. https://doi.org/10.1371/journal.pone.0162116.

Díaz, A.R., Rollock, L., Boodram, L.-L.G., Mahon, R., Best, S., Trotman, A., Van Meerbeeck, C.J., Fletcher, C., Dunbar, W., Lippi, C.A., Lührsen, D., Sorensen, C., Muñoz, Á.G., Ryan, S.J., Stewart-Ibarra, A.M., Lowe, R., 2024. A demand-driven climate services for health implementation framework: a case study for climate-sensitive diseases in caribbean small Island developing states. PLOS Clim. 3, e0000282. https://doi.org/10.1371/journal.pclm.0000282.

Da Re, D., Marini, G., Bonannella, C., Laurini, F., Manica, M., Anicic, N., Albieri, A., Angelini, P., Arnoldi, D., Blaha, M., Bertola, F., Caputo, B., De Liberato, C., della Torre, A., Flacio, E., Franceschini, A., Gradoni, F., Kadriaj, P., Lencioni, V., Del Lesto, I., La Russa, F., Lia, R.P., Montarsi, F., Otranto, D., L'Ambert, G., Rizzoli, A., Rombolà, P., Romiti, F., Stancher, G., Torina, A., Velo, E., Virgillito, C., Zandonai, F., Rosà, R., 2024. VectAbundance: a spatio-temporal database of Aedes mosquitoes observations. Sci. Data 11, 636. https://doi.org/10.1038/s41597-024-03482-y.

Da Re, D., Tordoni, E., Lenoir, J., Rubin, S., Vanwambeke, S.O., 2024. Towards causal relationships for modelling species distribution. J. Biogeogr. 51, 840–852. https://doi.org/10.1111/jbi.14775.

Da Re, D., Andreo, V., San Miguel, T.V., Blaha, M., Rosà, R., Rizzoli, A., Harrison, J., Sorek, S., Johnson, L.R., Huxley, P.J., 2025a. AedesTraits: a global dataset of temperature–dependent trait responses in Aedes mosquitoes. Sci. Data 12, 2033. https://doi.org/10.1038/s41597-025-06461-z.

Da Re, D., Deblauwe, I., Kern, E.I., Hermy, M., Romero, J.R., Tersago, K., Versteirt, V., Dumez, B., Houtsaeger, C., Rouffaer, L., Beck, O., Van Bortel, W., 2025b. A warming welcome? Belgium's increasing suitability for Aedes albopictus. Parasites Vectors 18, 491. https://doi.org/10.1186/s13071-025-07119-w.

Da Re, D., Marini, G., Bonannella, C., Laurini, F., Manica, M., Anicic, N., Albieri, A., Angelini, P., Arnoldi, D., Blaha, M., Bertola, F., Caputo, B., De Liberato, C., della Torre, A., Flacio, E., Franceschini, A., Gradoni, F., Kadriaj, P., Lencioni, V., Del Lesto, I., La Russa, F., Lia, R.P., Montarsi, F., Otranto, D., L'Ambert, G., Rizzoli, A., Rombolà, P., Romiti, F., Stancher, G., Torina, A., Velo, E., Virgillito, C., Zandonai, F., Rosà, R., 2025c. Modelling the seasonal dynamics of *Aedes albopictus* populations using a spatio-temporal stacked machine learning model. Sci. Rep. 15, 3750. https://doi.org/10.1038/s41598-025-87554-y.

Dieng, H., Rahman, G.M.S., Abu Hassan, A., Che Salmah, M.R., Satho, T., Miake, F., Boots, M., Sazaly, A., 2012. The effects of simulated rainfall on immature population dynamics of Aedes albopictus and female oviposition. Int. J. Biometeorol. 56, 113–120. https://doi.org/10.1007/s00484-011-0402-0.

Regione Emilia-Romagna, 2011. Controllo della Zanzara-Tigre: Analisi dei costi sostenuti dagli Enti Locali.

Erguler, K., Arca, A., Tsouloupas, G., Alten, B., Della Torre, A., Veljko Petrić, D., Koliou Mazeri, M., Christophides, G., Lelieveld, J., 2024. VEClim: An early warning decision support system for climate-sensitive vector activity and vector-borne disease risk assessment. Wellcome Open Res. 9, 697. https://doi.org/10.12688/wellcomeopenres.23122.1.

Eritja, R., Ruiz-Arrondo, I., Delacour-Estrella, S., Schaffner, F., Álvarez-Chachero, J., Bengoa, M., Puig, M.-Á., Melero-Alcíbar, R., Oltra, A., Bartumeus, F., 2019. First detection of Aedes japonicus in Spain: an unexpected finding triggered by citizen science. Parasites Vectors 12, 53. https://doi.org/10.1186/s13071-019-3317-y.

European Centre for Disease Prevention and Control, 2023. Aedes aegypti - Factsheet for experts [WWW Document]. URL. https://www.ecdc.europa.eu/en/disease-vectors/facts/mosquito-factsheets/aedes-aegypti. accessed 11.18.25.

Farooq, Z., Sjödin, H., Semenza, J.C., Tozan, Y., Sewe, M.O., Wallin, J., Rocklöv, J., 2023. European projections of West Nile virus transmission under climate change scenarios. One Health 16, 100509. https://doi.org/10.1016/j.onehlt.2023.100509.

Farooq, Z., Segelmark, L., Rocklöv, J., Lillepold, K., Sewe, M.O., Briet, O.J.T., Semenza, J.C., 2025. Impact of climate and *Aedes albopictus* establishment on dengue and chikungunya outbreaks in Europe: a time-to-event analysis. Lancet Planet. Health 9, e374–e383. https://doi.org/10.1016/S2542-5196(25)00059-2.

Ferraguti, M., Martínez-de La Puente, J., Brugueras, S., Millet, J.P., Rius, C., Valsecchi, A., Figuerola, J., Montalvo, T., 2023. Spatial distribution and temporal dynamics of invasive and native mosquitoes in a large Mediterranean city. Sci. Total Environ. 896, 165322. https://doi.org/10.1016/j.scitotenv.2023.165322.

Fesce, E., Marini, G., Rosà, R., Lelli, D., Cerioli, M.P., Chiari, M., Farioli, M., Ferrari, N., 2023. Understanding West Nile virus transmission: Mathematical modelling to quantify the most critical parameters to predict infection dynamics. PLOS Negl. Trop. Dis. 17, e0010252. https://doi.org/10.1371/journal.pntd.0010252.

Fesce, E., Marini, G., Rosà, R., Lelli, D., Cerioli, M.P., Chiari, M., Farioli, M., Ferrari, N., 2025. Are we doing our best to contain the spread of West Nile virus? Eval. Interv. Effic. Through Math. Model. Parasites Vectors 18, 499. https://doi.org/10.1186/s13071-025-07128-9.

Fischer, D., Thomas, S.M., Niemitz, F., Reineking, B., Beierkuhnlein, C., 2011. Projection of climatic suitability for Aedes albopictus Skuse (Culicidae) in Europe under climate change conditions. Glob. Planet. Change 78, 54–64. https://doi.org/10.1016/j.gloplacha.2011.05.008.

Garrido Zornoza, M., Caminade, C., Tompkins, A.M., 2024. The effect of climate change and temperature extremes on *Aedes albopictus* populations: a regional case study for Italy. J. R. Soc. Interface 21, 20240319. https://doi.org/10.1098/rsif.2024.0319.

Giraldo-Calderón, G.I., Emrich, S.J., MacCallum, R.M., Maslen, G., Dialynas, E., Topalis, P., Ho, N., Gesing, S., Consortium, the VectorBase, Madey, G., Collins, F.H., Lawson, D., 2015. VectorBase: an updated bioinformatics resource for invertebrate vectors and other organisms related with human diseases. Nucleic Acids Res. 43, D707–D713. https://doi.org/10.1093/nar/gku1117.

Guzzetta, G., Montarsi, F., Baldacchino, F.A., Metz, M., Capelli, G., Rizzoli, A., Pugliese, A., Rosà, R., Poletti, P., Merler, S., 2016. Potential risk of dengue and chikungunya outbreaks in Northern Italy based on a population model of Aedes albopictus (Diptera: Culicidae). PLoS Negl. Trop. Dis. 10, e0004762. https://doi.org/10.1371/journal.pntd.0004762.

Hasan, M.N., Rahman, M., Uddin, M., Ashrafi, S.A.A., Rahman, K.M., Paul, K.K., Sarker, M.F.R., Haque, F., Sharma, A., Papakonstantinou, D., Paudyal, P., Asaduzzaman, M., Zumla, A., Haider, N., 2025. The 2023 fatal dengue outbreak in Bangladesh highlights a paradigm shift of geographical distribution of cases. Epidemiol. Infect. 153, e3. https://doi.org/10.1017/S0950268824001791.

Healy, K.B., Dugas, E., Fonseca, D.M., 2019. Development of a degree-day model to predict egg hatch of Aedes albopictus. J. Am. Mosq. Control Assoc. 35, 249–257. https://doi.org/10.2987/19-6841.1.

Jebeile, J., 2024. From regional climate models to usable information. Clim. Change 177, 53. https://doi.org/10.1007/s10584-024-03693-7.

Johnson, B.W., Chambers, T.V., Crabtree, M.B., Filippis, A.M.B., Vilarinhos, P.T.R., Resende, M.C., Macoris, M.D.L.G., Miller, B.R., 2002. Vector competence of Brazilian Aedes aegypti and Ae. albopictus for a Brazilian yellow fever virus isolate. Trans. R. Soc. Trop. Med. Hyg. 96, 611–613. https://doi.org/10.1016/S0035-9203(02)90326-3.

Johnson, L.R., Cator, L., Rund, S.S.C., Ryan, S., Huxley, P.J., Pawar, S., 2023. VecTraits explorer. https://doi.org/10.7274/28020782.

Kern, E., Marini, G., Da Re, D., Dorigatti, I., 2026. Laboratory evidence of the effect of water availability on Aedes mosquito population dynamics: a scoping review. https://doi.org/10.32942/X29D3P.

Kraemer, M.U.G., Hay, S.I., Pigott, D.M., Smith, D.L., Wint, G.R.W., Golding, N., 2016. Progress and challenges in infectious disease cartography. Trends Parasitol. 32, 19–29. https://doi.org/10.1016/j.pt.2015.09.006.

Kramer, I.M., Kreß, A., Klingelhöfer, D., Scherer, C., Phuyal, P., Kuch, U., Ahrens, B., Groneberg, D.A., Dhimal, M., Müller, R., 2020. Does winter cold really limit the dengue vector Aedes aegypti in Europe? Parasites Vectors 13, 178. https://doi.org/10.1186/s13071-020-04054-w.

Kramer, I.M., Pfeiffer, M., Steffens, O., Schneider, F., Gerger, V., Phuyal, P., Braun, M., Magdeburg, A., Ahrens, B., Groneberg, D.A., Kuch, U., Dhimal, M., Müller, R., 2021. The ecophysiological plasticity of Aedes aegypti and Aedes albopictus concerning overwintering in cooler ecoregions is driven by local climate and acclimation capacity. Sci. Total Environ. 778, 146128. https://doi.org/10.1016/j.scitotenv.2021.146128.

Kramer, I.M., Pfenninger, M., Feldmeyer, B., Dhimal, M., Gautam, I., Shreshta, P., Baral, S., Phuyal, P., Hartke, J., Magdeburg, A., Groneberg, D.A., Ahrens, B., Müller, R., Waldvogel, A., 2023. Genomic profiling of climate adaptation in *Aedes aegypti* along an altitudinal gradient in Nepal indicates nongradual expansion of the disease vector. Mol. Ecol. 32, 350–368. https://doi.org/10.1111/mec.16752.

Kreß, A., Kuch, U., Oehlmann, J., Müller, R., 2016. Effects of diapause and cold acclimation on egg ultrastructure: new insights into the cold hardiness mechanisms of the Asian tiger mosquito *Aedes (Stegomyia) albopictus*. J. Vector Ecol. 41, 142–150. https://doi.org/10.1111/jvec.12206.

Kreß, A., Oppold, A.-M., Kuch, U., Oehlmann, J., Müller, R., 2017. Cold tolerance of the Asian tiger mosquito Aedes albopictus and its response to epigenetic alterations. J. Insect Physiol. 99, 113–121. https://doi.org/10.1016/j.jinsphys.2017.04.003.

Leach, M., Scoones, I., 2013. The social and political lives of zoonotic disease models: Narratives, science and policy. Soc. Sci. Med. 88, 10–17. https://doi.org/10.1016/j.socscimed.2013.03.017.

Lim, A.-Y., Jafari, Y., Caldwell, J.M., Clapham, H.E., Gaythorpe, K.A.M., Hussain-Alkhateeb, L., Johansson, M.A., Kraemer, M.U.G., Maude, R.J., McCormack, C.P., Messina, J.P., Mordecai, E.A., Rabe, I.B., Reiner, R.C., Ryan, S.J., Salje, H., Semenza, J.C., Rojas, D.P., Brady, O.J., 2023. A systematic review of the data, methods and environmental covariates used to map Aedes-borne arbovirus transmission risk. BMC Infect. Dis. 23, 708. https://doi.org/10.1186/s12879-023-08717-8.

Lounibos, L.P., Kramer, L.D., 2016. Invasiveness of *Aedes aegypti* and *Aedes albopictus* and Vectorial Capacity for Chikungunya Virus. J Infect Dis 214, S453–S458. https://doi.org/10.1093/infdis/jiw285.

Lowe, S., Browne, M., Boudjelas, S., De Poorter, M., 2004. 100 of the world's worst invasive alien species a selection from the global invasive species database.

Malle, J.T., Reyer, C.P., Amitai, Y., Augustynczik, A.L., Be'eri-Shlevin, Y., Ben-Zur, E., ... & Karger, D.N. (2025). When and where higher-resolution climate data improve impact model performance. *arXiv preprint* arXiv:2512.17739.

Manica, M., Marini, G., Solimini, A., Guzzetta, G., Poletti, P., Scognamiglio, P., Virgillito, C., Della Torre, A., Merler, S., Rosà, R., Vairo, F., Caputo, B., 2023. Reporting delays of chikungunya cases during the 2017 outbreak in Lazio region, Italy. PLoS Negl. Trop. Dis. 17, e0011610. https://doi.org/10.1371/journal.pntd.0011610.

Marini, G., Guzzetta, G., Baldacchino, F., Arnoldi, D., Montarsi, F., Capelli, G., Rizzoli, A., Merler, S., Rosà, R., 2017. The effect of interspecific competition on the temporal dynamics of Aedes albopictus and Culex pipiens. Parasites Vectors 10, 102. https://doi.org/10.1186/s13071-017-2041-8.

Marini, G., Arnoldi, D., Baldacchino, F., Capelli, G., Guzzetta, G., Merler, S., Montarsi, F., Rizzoli, A., Rosà, R., 2019a. First report of the influence of temperature on the bionomics and population dynamics of Aedes koreicus, a new invasive alien species in Europe. Parasites Vectors 12, 524. https://doi.org/10.1186/s13071-019-3772-5.

Marini, G., Guzzetta, G., Toledo, C.A.M., Teixeira, M., Rosà, R., Merler, S., 2019b. Effectiveness of Ultra-Low Volume insecticide spraying to prevent dengue in a non-endemic metropolitan area of Brazil. PLOS Comput. Biol. 15, e1006831. https://doi.org/10.1371/journal.pcbi.1006831.

Marini, G., Manica, M., Arnoldi, D., Inama, E., Rosà, R., Rizzoli, A., 2020. Influence of temperature on the life-cycle dynamics of Aedes albopictus population established at temperate latitudes: a laboratory experiment. Insects 11, 808. https://doi.org/10.3390/insects11110808.

Mbaoma, O.C., Thomas, S.M., Beierkuhnlein, C., 2024. Spatiotemporally explicit epidemic model for west nile virus outbreak in Germany: an inversely calibrated approach. J Epidemiol Glob Health 14, 1052–1070. https://doi.org/10.1007/s44197-024-00254-0.

McKenzie, B.A., Wilson, A.E., Zohdy, S., 2019. Aedes albopictus is a competent vector of Zika virus: a meta-analysis. PLoS ONE 14, e0216794. https://doi.org/10.1371/journal.pone.0216794.

Menegale, F., Manica, M., Del Manso, M., Bella, A., Zardini, A., Gobbi, A., Mignuoli, A.D., Mattei, G., Vairo, F., Vezzosi, L., Russo, F., Ferraro, F., Maraglino, F., Palamara, A.T., Poletti, P., Pezzotti, P., Merler, S., Riccardo, F., 2025. Risk assessment and perspectives of local transmission of chikungunya and dengue in Italy, a European forerunner. Nat. Commun. 16 (1), 6237. https://doi.org/10.1038/s41467-025-61109-1.

Miranda, M.Á., Barceló, C., Arnoldi, D., Augsten, X., Bakran-Lebl, K., Balatsos, G., Bengoa, M., Bindler, P., Boršová, K., Bourquia, M., Bravo-Barriga, D., Čabanová, V., Caputo, B., Christou, M., Delacour, S., Eritja, R., Fassi-Fihri, O., Ferraguti, M., Flacio, E., Frontera, E., Fuehrer, H.-P., García-Pérez, A.L., Georgiades, P., Gewehr, S., Goiri, F., González, M.A., Gschwind, M., Gutiérrez-López, R., Horváth, C., Ibáñez-Justicia, A., Jani, V., Kadriaj, P., Kalan, K., Kavran, M., Klobucar, A., Kurucz, K., Lucientes, J., Lühken, R., Magallanes, S., Marini, G., Martinou, A.F., Michelutti, A., Mihalca, A.D., Montalvo, T., Montarsi, F., Mourelatos, S., Muja-Bajraktari, N., Müller, P., Notarides, G., Osório, H.C., Oteo, J.A., Oter, K., Pajović, I., Palmer, J.R.B., Petrinic, S., Răileanu, C., Ries, C., Rogozi, E., Ruiz-Arrondo, I., Sanpera-Calbet, I., Sekulić, N., Sevim, K., Sherifi, K., Silaghi, C., Silva, M., Sokolovska, N., Soltész, Z., Sulesco, T., Šušnjar, J., Teekema, S., Valsecchi, A., Vasquez, M.I., Velo, E., Michaelakis, A., Wint, W., Petrić, D., Schaffner, F., Della Torre, A., , Consortium AIM-COST/AIM-Surv, Suchentrunk, C., Zechmeister, T., Gruber, E., Orehounig, G., Altgayer, G., Lex, F., Lebl, I., Zezula, D., Petermann, J.S., Oberleitner, F., Zittra, C., Brenner, T., Zimmermann, K., Klocker, L., Eigner, Barbara, Wortha, L., Pree, Stephanie, Jäger, S., Schwerte, T., Wieser, C., Heimburg, H., Gunczy, J., Paill, W., Jerrentrup, H., Pree, S., Daroglou, E., Eigner, B., Shahi-Barogh, B., Wortha, L.N., Svitok, M., Svitková, I., Oboňa, J., Barbušinová, E., Micocci, M., Albani, M., Serini, P., Cobre, P., Canals, M., Bellés, R., Erguler, K., Neira, M., Kelemenis, N., Vlachos, G., Karagiannis, A., Barandika, J.F., Cevidanes, A., Vázquez, P., Stroo, A., Horvat, Z., Stranj, M., Ignjatović-Ćupina, A., Dondur, D., Bogdanović, S., Srdić, V., Francuski, Z., Žunić, A., Posavec, M.C., Poje, D., Pismarovic, T., Markó, G., Inama, E., Manica, M., Rizzoli, A., Athanasiou, K., Muja, A., Qollaku, H., Amaro, F., Guerreiro, N., Alten, B., Gunay, F., Eryigit, O.Y., Yildirim, B., Yilmaz, S.O., Pehlivan, S., Neumann, U., Tauchmann, O., Vasic, A., Busmachiu, G., Lange, U., Schmidt-Chanasit, J., Angelidou, I., Panayiotou, C., Konstantinou, I., Sino, Gj., Mema, H., Veliko, A., Kollia, D., Mourafetis, F., Karras, V., Bisia, M., Bender, C., 2022. AIMSurv: First pan-European harmonized surveillance of Aedes invasive mosquito species of relevance for human vector-borne diseases. Gigabyte 2022, 1–11. https://doi.org/10.46471/gigabyte.57.

Nowell, L.S., Norris, J.M., White, D.E., Moules, N.J., 2017. Thematic analysis: striving to meet the trustworthiness criteria. Int. J. Qual. Methods 16, 1609406917733847. https://doi.org/10.1177/1609406917733847.

Nunes, J.B., Gurgel-Gonçalves, R., Cruvinel, V.R.N., Da Silva, E.N., Obara, M.T., Mota, N.O., Zolnikov, T.R., Yahouedo, G.A., Fouque, F., 2025. Multisectoral approaches to the prevention and control of vector-borne diseases: lessons learned from case studies. Parasites Vectors 18, 501. https://doi.org/10.1186/s13071-025-07181-4.

Padilla-Pozo, Á., Bartumeus, F., Montalvo, T., Sanpera-Calbet, I., Valsecchi, A., Palmer, J.R.B., 2024. Assessing and correcting neighborhood socioeconomic spatial sampling biases in citizen science mosquito data collection. Sci. Rep. 14, 22462. https://doi.org/10.1038/s41598-024-73416-6.

Palmer, J.R.B., Oltra, A., Collantes, F., Delgado, J.A., Lucientes, J., Delacour, S., Bengoa, M., Eritja, R., Bartumeus, F., 2017. Citizen science provides a reliable and scalable tool to track disease-carrying mosquitoes. Nat. Commun. 8, 916. https://doi.org/10.1038/s41467-017-00914-9.

Pennisi, F., Pinto, A., Borgonovo, F., Scaglione, G., Ligresti, R., Santangelo, O.E., Provenzano, S., Gori, A., Baldo, V., Signorelli, C., Gianfredi, V., 2026. Artificial intelligence models for forecasting mosquito-borne viral diseases in human populations: a global systematic review and comparative performance analysis. MAKE 8, 15. https://doi.org/10.3390/make8010015.

Poletti, P., Messeri, G., Ajelli, M., Vallorani, R., Rizzo, C., Merler, S., 2011. Transmission potential of chikungunya virus and control measures: the case of Italy. PLoS ONE 6, e18860. https://doi.org/10.1371/journal.pone.0018860.

Purse, B.V., Golding, N., 2015. Tracking the distribution and impacts of diseases with biological records and distribution modelling. Biol. J. Linn. Soc. L. 115, 664–677. https://doi.org/10.1111/bij.12567.

Purse, B.V., Darshan, N., Kasabi, G.S., Gerard, F., Samrat, A., George, C., Vanak, A.T., Oommen, M., Rahman, M., Burthe, S.J., Young, J.C., Srinivas, P.N., Schäfer, S.M., Henrys, P.A., Sandhya, V.K., Chanda, M.M., Murhekar, M.V., Hoti, S.L., Kiran, S.K., 2020. Predicting disease risk areas through co-production of spatial models: the example of Kyasanur Forest Disease in India's forest landscapes. PLoS Negl. Trop. Dis. 14, e0008179. https://doi.org/10.1371/journal.pntd.0008179.

Radici, A., Hammami, P., Cannet, A., L'Ambert, G., Lacour, G., Fournet, F., Garros, C., Guis, H., Fontenille, D., Caminade, C., 2025. Aedes albopictus is rapidly invading its climatic Niche in France: wider implications for biting nuisance and arbovirus control in Western Europe. Glob. Change Biol. 31, e70414. https://doi.org/10.1111/gcb.70414.

Restif, O., Hayman, D.T.S., Pulliam, J.R.C., Plowright, R.K., George, D.B., Luis, A.D., Cunningham, A.A., Bowen, R.A., Fooks, A.R., O'Shea, T.J., Wood, J.L.N., Webb, C.T., 2012. Model-guided fieldwork: practical guidelines for multidisciplinary research on wildlife ecological and epidemiological dynamics. Ecol. Lett. 15, 1083–1094. https://doi.org/10.1111/j.1461-0248.2012.01836.x.

Reuss, F., Wieser, A., Niamir, A., Bálint, M., Kuch, U., Pfenninger, M., Müller, R., 2018. Thermal experiments with the Asian bush mosquito (Aedes japonicus japonicus) (Diptera: Culicidae) and implications for its distribution in Germany. Parasites Vectors 11, 81. https://doi.org/10.1186/s13071-018-2659-1.

Rezza, G., 2012. Aedes albopictus and the reemergence of Dengue. BMC Public Health 12, 72. https://doi.org/10.1186/1471-2458-12-72.

Rogers, D.J., 2006. Models for vectors and vector-borne diseases. Advances in Parasitology. Elsevier, pp. 1–35. https://doi.org/10.1016/S0065-308X(05)62001-5.

Roiz, D., Pontifes, P.A., Jourdain, F., Diagne, C., Leroy, B., Vaissière, A.-C., Tolsá-García, M.J., Salles, J.-M., Simard, F., Courchamp, F., 2024. The rising global economic costs of invasive *Aedes* mosquitoes and *Aedes*-borne diseases. Sci. Total Environ. 933, 173054. https://doi.org/10.1016/j.scitotenv.2024.173054.

Romiti, F., Casini, R., Magliano, A., Ermenegildi, A., De Liberato, C., 2022. Aedes albopictus abundance and phenology along an altitudinal gradient in Lazio region (central Italy). Parasites Vectors 15, 92. https://doi.org/10.1186/s13071-022-05215-9.

Rund, S.S.C., Ryan, S.J., Huxley, P.J., Lippi, C.A., Cator, L., Samraat Pawar, Johnson, L. R., 2023. VecDyn Explorer. https://doi.org/10.7274/10083626.

Ryan, S.J., Carlson, C.J., Mordecai, E.A., Johnson, L.R., 2019. Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. PLoS Negl. Trop. Dis. 13, e0007213. https://doi.org/10.1371/journal.pntd.0007213.

Ryan, S.J., Huxley, P.J., Lippi, C.A., Pawar, S., Cator, L., Rund, S.S.C., Johnson, L.R., 2025. MIReVTD, a minimum information standard for reporting vector trait data. GigaScience, giag020. https://doi.org/10.1101/2025.01.27.634769.

Sacco, C., Liverani, A., Venturi, G., Gavaudan, S., Riccardo, F., Salvoni, G., Fortuna, C., Marinelli, K., Marsili, G., Pesaresi, A., Grané, C.M., Mercuri, I., Manica, M., Caucci, S., Morelli, D., Sebastianelli, L., Marcacci, M., Ferraro, F., Di Luca, M., Pascucci, I., Merakou, C., Duranti, A., Pati, I., Lombardini, L., Fiacchini, D., Filipponi, G., Maraglino, F., Palamara, A.T., Poletti, P., Pezzotti, P., Filippetti, F., Merler, S., Del Manso, M., Menzo, S., Marche dengue outbreak group, 2024. Autochthonous dengue outbreak in Marche Region, Central Italy, August to October 2024. Eurosurveillance 29. https://doi.org/10.2807/1560-7917.ES.2024.29.47.2400713.

Salamon, Peter; Ramos Gomes, Gonçalo Nuno; Sperzel, Tim; Radke-Fretz, Marco; Schweim, Christoph; Ziese, Markus; Lemke, Carina-Denise; Russo, Carlo; Grimaldi, Stefania (2026): EMO: A high-resolution multi-variable gridded meteorological data set for Europe. European Commission, Joint Research Centre http://data.europa.eu/89h/0bd84be4-cec8-4180-97a6-8b3adaac4d26.

San Miguel, T.V., Da Re, D., Andreo, V., 2024. A systematic review of Aedes aegypti population dynamics models based on differential equations. Acta Trop. 260, 107459. https://doi.org/10.1016/j.actatropica.2024.107459.

Schaffner, F., Medlock, J.M., Bortel, W.V., 2013. Public health significance of invasive mosquitoes in Europe. Clin. Microbiol. Infect. 19, 685–692. https://doi.org/10.1111/1469-0691.12189.

Sedda, L., Morley, D.W., Braks, M.A.H., De Simone, L., Benz, D., Rogers, D.J., 2014. Risk assessment of vector-borne diseases for public health governance. Public Health 128, 1049–1058. https://doi.org/10.1016/j.puhe.2014.08.018.

Sedda, L., Wrench, E., Moore, T.C., Wolfe, K., Tangena, J.-A.A., Brown, H.E., 2025. Challenges in the surveillance and control of mosquito-borne diseases in Europe and United States. The perspective from public health experts. One Health 21, 101133. https://doi.org/10.1016/j.onehlt.2025.101133.

Sillero, N., Arenas-Castro, S., Enriquez-Urzelai, U., Vale, C.G., Sousa-Guedes, D., Martínez-Freiría, F., Real, R., Barbosa, A.M., 2021. Want to model a species niche? A step-by-step guideline on correlative ecological niche modelling. Ecol. Model. 456, 109671. https://doi.org/10.1016/j.ecolmodel.2021.109671.

Souza-Neto, J.A., Powell, J.R., Bonizzoni, M., 2019. Aedes aegypti vector competence studies: a review. Infect. Genet. Evol. 67, 191–209. https://doi.org/10.1016/j.meegid.2018.11.009.

Stewart-Ibarra, A.M., Romero, M., Hinds, A.Q.J., Lowe, R., Mahon, R., Van Meerbeeck, C. J., Rollock, L., Gittens-St Hilaire, M., St Ville, S., Ryan, S.J., Trotman, A.R., Borbor-Cordova, M.J., 2019. Co-developing climate services for public health: stakeholder needs and perceptions for the prevention and control of Aedes-transmitted diseases in the Caribbean. PLOS Negl. Trop. Dis. 13, e0007772. https://doi.org/10.1371/journal.pntd.0007772.

Stewart-Ibarra, A.M., Rollock, L., Best, S., Brown, T., Diaz, A.R., Dunbar, W., Lippi, C.A., Mahon, R., Ryan, S.J., Trotman, A., Van Meerbeeck, C.J., Lowe, R., 2022. Co-learning during the co-creation of a dengue early warning system for the health sector in Barbados. BMJ Glob. Health 7, e007842. https://doi.org/10.1136/bmjgh-2021-007842.

Thomas, S.M., Obermayr, U., Fischer, D., Kreyling, J., Beierkuhnlein, C., 2012. Low-temperature threshold for egg survival of a post-diapause and non-diapause European aedine strain, Aedes albopictus (Diptera: Culicidae). Parasites Vectors 5, 100. https://doi.org/10.1186/1756-3305-5-100.

Tippelt, L., Werner, D., Kampen, H., 2020. Low temperature tolerance of three Aedes albopictus strains (Diptera: Culicidae) under constant and fluctuating temperature scenarios. Parasites Vectors 13, 587. https://doi.org/10.1186/s13071-020-04386-7.

Tjaden, N.B., Caminade, C., Beierkuhnlein, C., Thomas, S.M., 2018. Mosquito-borne diseases: advances in modelling climate-change impacts. Trends Parasitol. 34, 227–245. https://doi.org/10.1016/j.pt.2017.11.006.

Van Kleef, E., Van Bortel, W., Arsevska, E., Busani, L., Dellicour, S., Di Domenico, L., Gilbert, M., Van Elsland, S.L., Kraemer, M.U., Lai, S., Lemey, P., Merler, S., Milosavljevic, Z., Rizzoli, A., Simic, D., Tatem, A.J., Teisseire, M., Wint, W., Colizza, V., Poletto, C., 2025. Modelling practices, data provisioning, sharing and dissemination needs for pandemic decision-making: a European survey-based modellers' perspective, 2020 to 2022. Eurosurveillance 30. https://doi.org/10.2807/1560-7917.ES.2025.30.42.2500216.

Venkatesan, P., 2024. Global upsurge in dengue in 2024. Lancet Infect. Dis. 24, e620. https://doi.org/10.1016/S1473-3099(24)00609-1.

Walther, D., Kampen, H., 2017. The Citizen Science Project 'Mueckenatlas' Helps Monitor the Distribution and Spread of Invasive Mosquito Species in Germany. J. Med. Entomol. 54, 1790–1794. https://doi.org/10.1093/jme/tjx166.

Wieser, A., Reuss, F., Niamir, A., Müller, R., O'Hara, R.B., Pfenninger, M., 2019. Modelling seasonal dynamics, population stability, and pest control in Aedes japonicus japonicus (Diptera: Culicidae). Parasites Vectors 12, 142. https://doi.org/10.1186/s13071-019-3366-2.

Wilby, R.L., Dessai, S., 2010. Robust adaptation to climate change. Weather 65, 180–185. https://doi.org/10.1002/wea.543.

Wint, G.R.W., Balenghien, T., Berriatua, E., Braks, M., Marsboom, C., Medlock, J., Schaffner, F., Van Bortel, W., Alexander, N., Alten, B., Czwienczek, E., Dhollander, S., Ducheyne, E., Gossner, C.M., Hansford, K., Hendrickx, G., Honrubia, H., Matheussen, T., Mihalca, A.D., Petric, D., Richardson, J., Sprong, H., Versteirt, V., Briet, O., 2023. VectorNet: collaborative mapping of arthropod disease vectors in Europe and surrounding areas since 2010. Eurosurveillance 28. https://doi.org/10.2807/1560-7917.ES.2023.28.26.2200666.

World Health Organization, 2020. Multisectoral Approach for the Prevention and Control of Vector-Borne Diseases, 1st ed. World Health Organization, Geneva.

Zurell, D., Franklin, J., König, C., Bouchet, P.J., Dormann, C.F., Elith, J., Fandos, G., Feng, X., Guillera-Arroita, G., Guisan, A., Lahoz-Monfort, J.J., Leitão, P.J., Park, D.S., Peterson, A.T., Rapacciuolo, G., Schmatz, D.R., Schröder, B., Serra-Diaz, J.M., Thuiller, W., Yates, K.L., Zimmermann, N.E., Merow, C., 2020. A standard protocol for reporting species distribution models. Ecography 43, 1261–1277. https://doi.org/10.1111/ecog.04960.